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MORPHOLOGICAL CHARACTERISTICS OF THE GIANH RIVER (FROM CO CANG TO CUA GIANH) IN RELATION TO THE EROSION AND ACCUMULATION

Hai Nguyen Tien[1,*], Dang Vu Hai[1], Phuc La The[2], Ha Nguyen Thai[3]

[1]*Institute of Marine Geology and Geophysics, VAST, Vietnam*
[2]*Vietnam Nation Museum of Nature, VAST, Vietnam*
[3]*Center for Scientific Information, VAST, Vietnam*
[*]E-mail: nguyentienhai.2011@gmail.com

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Abstract. On the basis of morphological characteristics and erosion - accumulation of sediment, it is possible to divide the stretch of the Gianh river from Co Cang to Cua Gianh (about 54 km in length) into 3 sections as follows: Meandering channel (from Co Cang to Tien Xuan isles): The length of the channel is 27.69 km and the width of the channel is 80–250 m. The channel is in the form of a meandering, narrow riverbed, flow plays a dominant role, deposition activities develop strongly at the convex side, while erosion occurs strongly in the concave side (cut side); Braided channel (from Tien Xuan Isles to Quang Phu): The length of the channel is 17.06 km and the width of the channel is 800–2,200 m. The channel is straight, the river bed is large and the depth of the river bed is 2–11 m. Sedimentation occurs mainly at the bottom of the channel and creates bar in the middle of the channel; Straight channel (from Quang Phu to Cua Gianh): The length of the channel is 9.23 km and the width of the channel is 800–1,000 m. The channel is straight and the depth of the river bed is 8–12.5 m. In addition to the role of river flow, it is strongly influenced by marine dynamics. The erosion and accretion activities occur mainly in estuaries. The results above show trend of river development: i) Meandering channel is the most vulnerable to changes for morphology of channel by erosion and accretion of sediment and can create 1–2 horseshoe pools by the river change line; ii) Braided channel mainly changes in the bottom of channel by the formation of channel bar; iii) Straight channel mainly changes in the estuary (the mouth of the river can be moved, enlarged or narrowed).

Keywords: Gianh river, bank erosion, meandering channel, deposition.

INTRODUCTION

The length of the Gianh river is 152 km. This river originates in the Truong Son Mountains in the West, where the height is over 2,000 m. The basin of the Gianh river is 4,680 km² with an average slope of 19.2%. The largest width of the Gianh river is about 2,200 m in Quang Hai island [1].

As the river flows through the Quaternary formations, the morphological characteristics of the river change due to the effects of erosion and accretion as well as the impact of marine dynamics. These changes are more detrimental to human and regional environment. The problem of studying the morphology of the river and the fluctuations of the Gianh river downstream has so far been largely ignored.

The study area located downstream of Gianh river, Quang Binh province. This area is the channel of Gianh river from Co Cang to

Cua Gianh (fig. 1). Co Cang area (at Nam Son, Mai Hoa, Tuyen Hoa) is the confluence of the Gianh river and Trooc river.

CHARACTERISTICS OF NATURAL CONDITIONS IN THE STUDY AREA

Features of the rain regime. The Northern Quang Binh where has tropical monsoon climate is under the influence of the climate with 2 seasons (the dry season from April to August and rainy season from September to March of next year) [1]. The rainfall averages from 1,500 mm to 2,000 mm each year. The rainy period focuses on September, October and November [1].

Characteristics of topography and geomorphology. The valley of the Gianh river (section from Co Cang to Cua Gianh) is a narrow valley with a length of about 54 km (fig. 1). Along the Northern and Southern edges of the river valleys, there are hills and mountains with a height of 20–400 m. In the river from Quang Lien to Gianh bridge, there are 6 isles. These isles are mudflats between rivers.

Characteristics of geology. According to Geological and Mineral Map (1/200,000 scale, Mahaxay - Dong Hoi area [2]), the geological formations in the study area are the formations from Devon to Quaternary. On the Southern edge of the river valley, there are the formations: Ban Giang (D_2e*bg*), Muc Bai (D_2*mb*), Dong Tho (D_3fr*đt*), La Khe (C_1*lk*) and Bac Son (C-P*bs*); while on the Northern edge of the valley, there are the formations: Dong Trau (T_2a *đt*) and Dong Do (T_3n-r *đđ*).

Ban Giang Formation is composed of three components: Grey quartz sandstone bearing chert nests intercalated with black siltstone; Grey-yellowish quartz sandstone; Black shale intercalated with dark-grey siltstone, quartzitic sandstone; 1,090 m thick.

Muc Bai Formation consists of black thin-bedded limestone and quartz sandstone; 760 m thick.

Dong Tho Formation is composed of two components: Light-grey medium-grained quartz sandstone, siltstone and shale; Quartz sandstone, coaly siltstone, coaly shale; 220 m thick.

La Khe Formation is composed of three components: Conglomerate with quartz and limestone pebbles, limestone breccia, marl; Grey to dark-grey cherty limestone with interbeds of black banded marl; Ashen marl with some interbeds of pseudo-oolithic limestone; 230 m thick.

Bac Son Formation is composed of four components: Thin-to-medium - bedded dark-grey limestone; Pale breccia-like limestone, oolithic limestone intercalated with grey, dark-grey, medium-bedded to massive cherty limestone; Grey-brown thin-to medium-bedded oolithic limestone intercalated with greenish, dark-grey cherty limestone containing chert nests; Light-coloured feebly recrystallized limestone, slightly roseate cherty limestone, white oolithic limestone; 700–900 m thick.

Dong Trau Formation occupies large areas in the North of Gianh river. It is discriminated into two-subformations: Basal conglomerate, medium-grained sandstone, porphyritic rhyolite, 1,500–1,700 m thick; Sandy siltstone, fine sandstone, sericite schist, 1,500 m thick.

Dong Do Formation is composed of two components: Sandy siltstone, argillite with lenses of coaly shale and interbeds of shale; Grey sandy siltstone, brown-yellowish medium-bedded fine sandstone; 225 m thick.

River valley plain is formed by the Quaternary sediments of the formations: Middle Holocene sediments and Late Holocene sediments.

Tu Loan Formation (Q_1^3*tl*) is composed of yellow-grey silt sand mixed with grit bearing laterite lumps. The exposed on the surface part of the formation has been seen in the margin of the plains, at the absolute height of 15–25 m, in places up to 30 m, where the plain contacts with the hilly zone. The common thickness of the Tu Loan Formation is about 12–13 m.

Fluvio-marine Middle Holocene deposits (amQ_2^2) are largely distributed on the absolute height of 4–5 m. They are composed of yellow, greenish-grey, dark-greys silt, clay and minor sand. The thickness reaches 25–40 m.

Fluvial Upper Holocene deposits (aQ_2^3) are distributed along river and books in the form of sand banks, river islet with different composition.

Marine-eolian Upper Holocene deposits (mvQ_2^3) are distributed mainly along the seashore parallel with the shoreline in a width of 3–4 km. They are composed of white-grey, fine-to medium-grained quartz sand, bearing muscovite scales, shell fragments of marine molluscs. The common thickness reaches 19 m.

Characteristics of Gianh river flow. The average annual water of the Gianh river is 7.95 km³ (about 252 m³/s). River flow depends mainly on rainfall regime, in particular, the flood season occurs from September to November (about 60–75% of the annual flow) and the annual flow module is 53.8 l/s.km². The muddy sand amount transported by the Gianh river is about $1.93.10^5$ tonnes/year, corresponding to an average turbidity of 192 g/m³ [1].

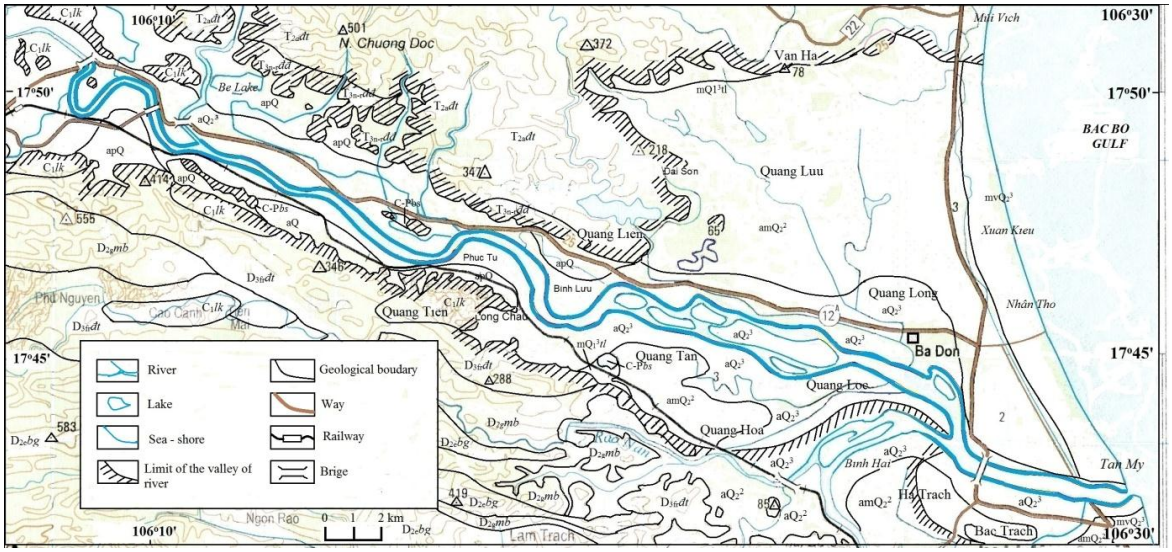


Fig. 1. Scheme showing the valley of the Gianh river (from Co Cang to Cua Gianh)
Note: $D_{2e}bg$. Ban Giang Formation; $D_{2g}mb$. Muc Bai Formation; $D_{3fr}dt$. Dong Tho Formation; C_1lk. La Khe Formation; C-P*bs*. Bac Son Formation; $T_{2a}dt$. Dong Trau Formation; $T_{3n\text{-}r}dd$. Dong Tho Formation; mQ_1^3tl. Tu Loan Formation; amQ_2^2. Middle Holocene Quaternary; aQ_2^3. Upper Holocene Quaternary; mvQ_2^3. Upper Holocene Quaternary; Q. Undivided Quaternary

METHODS AND MATERIALS

In the process of development and evolution, because of the effect of river flow, so the morphological characteristics of the river are different or fluctuate in different sections. Reineck, H. E., and Singh, I. B., [3] divided river sections as follows:

Straight channels: Straight channels possess a negligible sinuosity over a distance many times greater than the channel width (fig. 2a). As mentioned above straight channels are rare. Thalweg of straight channels is sinuous, and shows deeper parts (pools) alternating with shallower parts (riffles). Flow and depositional patterns are similar to those in meandering channels. Straight channels can shift their position by lateral accretion. Erosion takes place along pools and deposition on sediment bars. Straight channels are rather rare and exist only over short distances.

Braided channels: Braided rivers are characterized by wide channels, and rapid and continuous shifting of the sediment and the position of channels (fig. 2b). Braided channels are marked by successive division and rejoinings of the flow around alluvial islands. The main channels are divided into several channels which meet and are redivided.

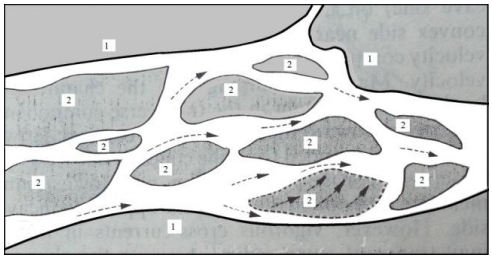
Channel bars which divide the stream into several channels at low flow are often submerged during high flow.

One or more alluvial islands or channel bars may be present in a given channels cross-section. The bars tend to be built up by the addition of sediment at the downstream end and on the lateral parts. The upstream end is partly eroded. The channel bars are composed of coarser-grained lag deposits of the stream which could not be carried by the flow. Once such a channel bar is formed, it may become stabilized by deposition of fine-grained sediment on the top during high flows and may become covered by vegetation.

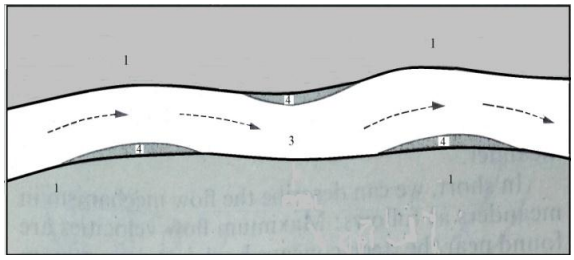
Meandering channels: Leopold and Wolman (1957, quoted from source: [3]) called the river reaches, meandering if sinuosity of the river is more than 1.5 (fig. 2c). There seems to be a certain fundamental relationship between the width of a channel and the meander length, and the channel width and the radius of curvature. Meandering channels possess well-defined pools and sediment bars joined by riffles. Sediment bars of meandering channels are better known as point bars, and constitute the major depositional feature produced as a result of channel action.

The lateral velocity component is 10% to 20% of the downstream velocity. Material slumping into the channel by bank caving is caught in the transverse component and carried toward the middle of the channel. However, material eroded from the concave side tends to be deposited on the point bar of the next downstream meander and not on the point bar opposite concave side.

The study and division of the river sections of the Gianh river (from Co Cang to Cua Gianh) are conducted according to the classification of Reineck, H. E., and Singh, I. B., [3].



b)



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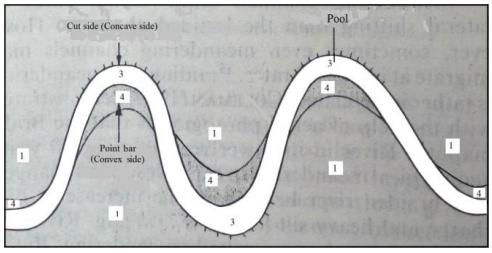

c)

Fig. 2. Types of the channel [3]
a) Straight Channel, b) Braided Channel, c) Meandering Channel
1) River-side, 2) Channel bar, 3) Pool, 4) Point bar
- - - -> Riffle

In the article, the author uses the meandering coefficient as follows: i) Straight channel: K_{mc} = 1.00; ii) Low meandering channel: 1.00 < K_{mc} ≤ 1.20; iii) Medium (overage) meandering channel: 1.20 < K_{mc} ≤ 1.35; iv) High meandering channel: 1.35 < K_{mc} ≤ 1.50; v) Very high meandering channel: K_{mc} > 1.50. Very high meandering channel corresponds to the meandering channel according to the classification of Leopold and Wolman (1957).

Materials and data used in the article are the survey materials of the VAST05.05/17–18 Project, 2017–2018 (Two survey lines along the Southern and Northern banks of the river and seven survey lines cross the river, fig. 3)

and the remote sensing and the satellite image on Google map and other materials.

Depth of the river is measured by Hondex PS-7 and measuring pole and plumb. Sedimentary samples is taken by the sample (weight about 10 kg). Sedimentary samples were analyzed at the laboratory - analysis department. Remote sensing is a Landsat image taken in December 2014 with a resolution of 30 m. Remote sensing images are used to define mudflats, riverbanks,...

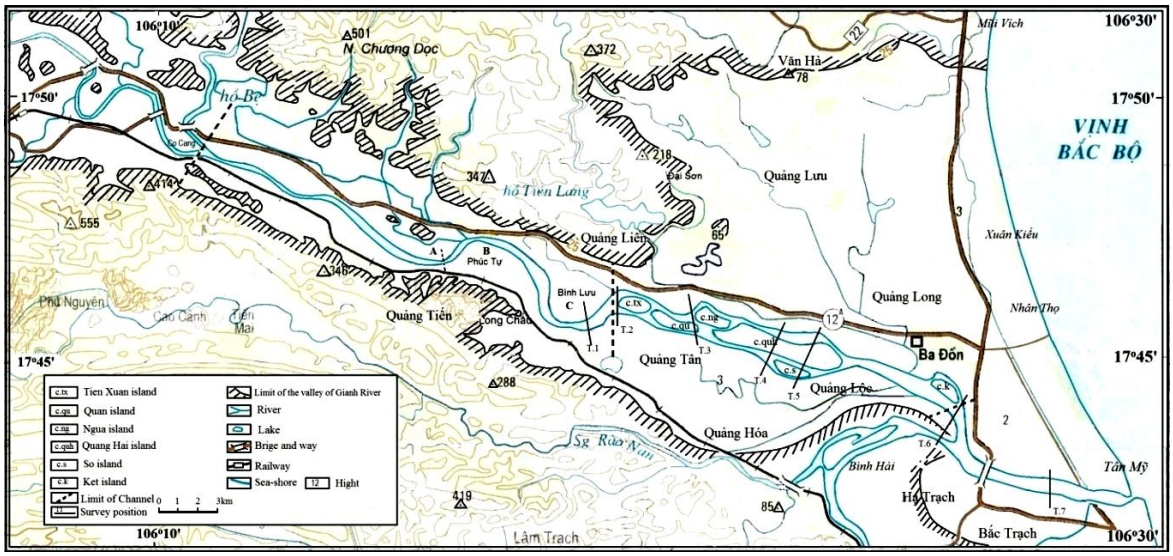

Fig. 3. Scheme showing the channels of the Gianh river: From Co Cang to Cua Gianh
T.1——: Position of the survey, A, B, C: Convex side

RESEARCH RESULTS

The length of Gianh river from Co Cang to Cua Gianh is 54.62 km and the length of valley of the river is 46.15 km, so this channel is a meandering channel with low level (K_{mc} = 1.18).

Based on the actual survey and remote sensing data, the Gianh River from Co Cang to Cua Gianh can be divided as follows (table 1, fig. 3):

The channel from Co Cang to Tien Xuan island: Meandering channel.

The length of this channel is 27.69 km and the length of valley is 20.77 km and meandering coefficient (K_{mc}) is 1.33. With the value of K_{mc} =1.33, this channel is a medium meandering channel.

In this channel, the accretion activity forms the coastal alluvial area on the convex side, but the bank erosion at the river-side and the bottom on the opposite side.

This channel consists of two sub - sections: i) the channel from Co Cang to Quang Tien (near Lac Son railway station) and ii) the channel from Quang Tien to Tien Xuan island.

First sub-section of river is a medium meandering channel. This channel has the length of valley of 13.15 km and the river length is 17.61 km and meandering coefficient (K_{mc}) is 1.30.

Second sub-section of river has the length of valley of 7.62 km and the river length is 10.62 km and meandering coefficient (K_{mc}) is 1.34. And so this channel is also a medium meandering channel, but at a higher level than first sub - section.

Typical features in the meandering channel are three convex sides and three concave sides: i) Mai Hoa and Tien Hoa convex sides on the Northern bank (fig. 4a–4c) and Long Chau convex side on the Southern bank (fig. 5b); ii) three concave sides correspond to three convex sides: Lac Son and Long Chau concave sides on the Southern bank

and Van Hoa concave side on the Northern bank. The meandering coefficient of these three channels: $K_{mc}A = 1.28$; $K_{mc}B = 1.60$ and $K_{mc}C = 2.00$.

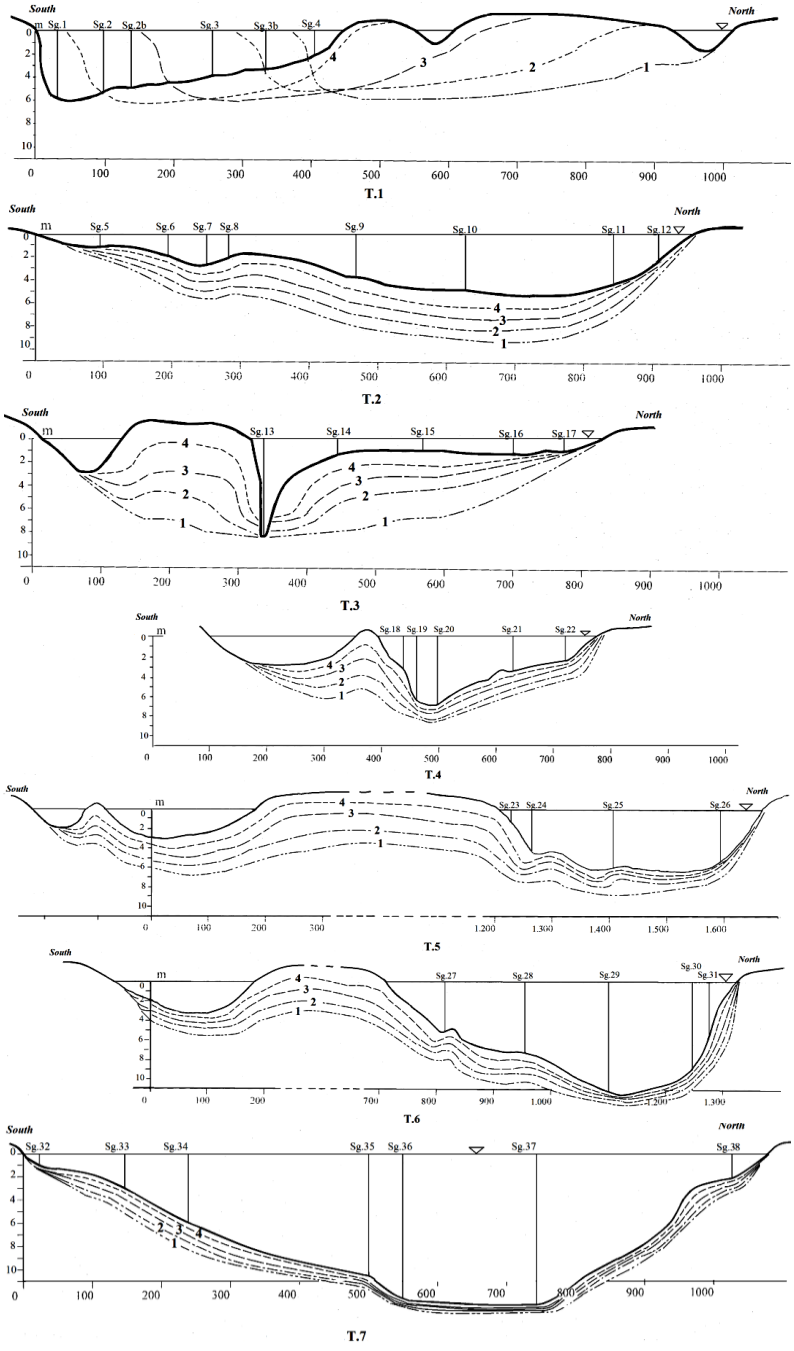

Fig. 4. Scheme showing the section of survey lines (According to survey data of the Project VAST05.05/17–18, April and May 2018)
▬: River bed, ▽: Water-surface, Sg: Survey points, - -4- -: Development of river bed over time, T1, T2,... T7: Survey lines

Table 1. Characteristics of the channels of Gianh river (from Co Cang to Cua Gianh)

Channel		Characteristics of the channel				Development and evolution
		Length of valley (km)	Length of channel (km)	Width of channel (m)	K_{mc}	
Meandering channel (Co Cang - Tien Xuan	First sub-section	13.15	17.01	0.3–0.46	1.29	Strongly change
	Second sub-section	7.62	10.62	0.45–0.50	1.34	Very strongly change
Braided channel (Tien Xuan - Quang Phu)		Length of channel: 17.06 km; Width of channel: 0.80–2.10 km				Change in the middle of the channel
Straight channel (Quang Phu - Cua Gianh)		Length of channel: 9.23 km; Width of channel: 0.80–1.00 km				Change little (Excluding Cua Gianh area)

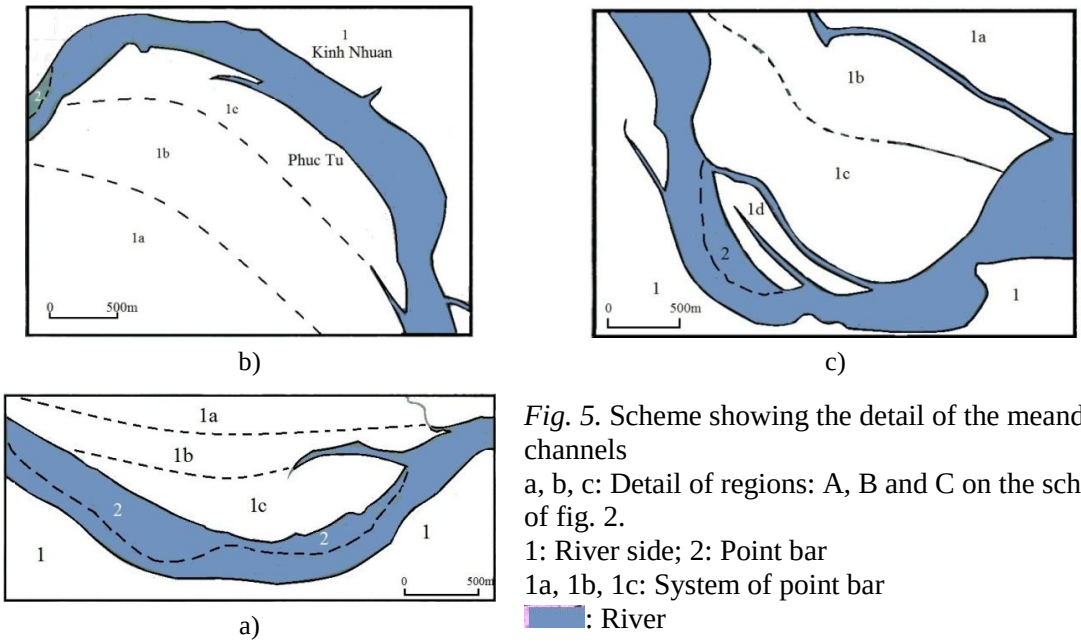

Fig. 5. Scheme showing the detail of the meandering channels
a, b, c: Detail of regions: A, B and C on the scheme of fig. 2.
1: River side; 2: Point bar
1a, 1b, 1c: System of point bar
: River

There are some small flows on the convex banks. These flows are the vestiges of the Gianh river during the development of the convex side.

Braided channel: Tien Xuan - Quang Phu.

The length of the braided channel is 17.06 km and the width of channel is about 0.80–2.20 km. The depth of the river bed is about from 5.0 m to 11.5 m (fig. 4: T.3, T.4, T.5 and T.6). At the present, there are six isles (mudflats in the middle of the river) on the braided channel from Tien Xuan to Quang Phu: Tien Xuan, Con Quan, Con Ngua, Con Se, Quang Hai and Con Ket isles.

The erosion and sedimentation in this channel activities along the banks of the islands have been quite strong and complicated, such as the Northern and North-Western side of Quang Hai island are eroded with high speed (about 15 m/year), especially during the rainy season (fig. 6c–6d).

Straight channel: Quang Phu - Cua Gianh.

The length of this channel is 9.23 km and the width of channel is about 0.8–1.0 km. The channel is straight and the depth of the river bed is about from 8.0 m to 12.5 m (fig. 4: T.7). In this channel, in addition to the role of river flow, it is strongly influenced by marine dynamics. The erosion and sedimentation activities occur mainly in estuaries by the relationship between river flow and sea dynamics.

a)

b)

c)

e)

d)

Fig. 6. Images of river bank erosion in Gianh river: a: Erosion in Mai Hoa concave side (According to survey of the Project VAST05.05/17-18, April and May 2018); b: Erosion in Long Chau concave side, Phong Hoa, Tuyen Hoa (http://www.baoxaydung, truy cập 11/5/2017); c, d: Erosion in Northern shore of Quang Hai Island (http://www.giadinh.net.vn, truy cập 16/10/2009); e: Erosion in Van Hoa concave side near Lac Son railway station (https://mothegioi.vn, truy cập 15/10/2016)

DISCUSSIONS

In braided channel, hydrodynamic regime in the confluence of the river is complicated by the interaction between river flow and tidal surges. As a result, sediment transported by the river is deposited there and forming mudflats in the middle of the river. Accumulation activity is strongest in the dry season, but during the rainy season, the speed of the river flow is very strong because of heavy rain, so the mudflats in the channel are strongly eroded (fig. 6c–6d). As such, the changes in braided channel mainly occur in the middle of the river bed, while the changes on the banks of river are not significant.

Meandering channel: As erosion-accretion activity occurs strongly, so this channel can be strongly changed in morphological characteristics of the channel. This changes increase the meandering of the channel and the risk of looting can create a horseshoe lake.

According to Leopold and Wolman (1957) [3], during the development of the straight channel (from Quang Phu to Cua Gianh), sediment bars will appear along the shore (fig. 1a). However, because the straight channel is the channel of the estuary area, therefore, due to the strong influence of the waves and tides, it is difficult to form sediment bars, while it is possible to form sand bars at the mouth of the river. These sand bars can change the mouth of

the river. The mouth of the Gianh river can be moved, enlarged or narrowed.

Thus, in the prevention of shoreline erosion in the Gianh river, the most important areas are the meandering channel and the islands in braided channel and the mouth of the Gianh river.

CONCLUSIONS

The Gianh river from Co Cang to Cua Gianh (about 54 km in length) has three sections as follows:

Meandering channel (from Co Cang to Tien Xuan isles): The channel is in the form of a meandering, narrow riverbed, flow plays a dominant role, accretion activities develop strongly at the convex side, while erosion occurs strongly in the concave side (cut side). Meandering channel is the most vulnerable to changes for morphology of channel by erosion and accretion of sediment.

Braided channel (from Tien Xuan isles to Quang Phu): The channel is straight, the river bed is large. Sedimentation occurs mainly at the bottom of the channel and creates bar in the middle of the channel. This channel mainly changes in the bottom of channel by the formation of channel bar.

Straight channel (from Quang Phu to Cua Gianh): The channel is straight, the river bed is large. In addition to the role of river flow, it is strongly influenced by marine dynamics. The erosion and sedimentation activities occur mainly in estuaries.

The general trend of the development of the Gianh river (from Co Cang to Cua Gianh): i) Strong changes in the meandering channel can create 1–2 horseshoe pools by the river change line; ii) Braided channel mainly changes in the bottom and the width of the river does not change; iii) In straight channel, the mouth of the river can be moved or narrowed with a small extent.

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REFERENCES

[1] Tran Thanh Toan (Ed.), Nguyen Van Nha, Le Quang Chien, Truong Xuan Diu, Nguyen Van Thanh, Dang Van Hoa, 1991. Quang Binh: Natural Conditions, Environmental Resources, Socio-economic and Development, Department of Science and Technology, Quang Binh province, p. 166, printed at the statistics department of advertising, Dong Hoi.

[2] Tran Tinh (Ed.), Dinh Cong Hung, Le Van Lam, Ngo Trinh Hieu, Nguyen Dinh Khanh, Nguyen Phu Vinh, Nguyen Thac Thu, Nguyen Dac Lu, Vu Huy Phuc, Vu Mạnh Dien, 1996. Geology and Mineral Resources of Mahaxay - Dong Hoi, Scale 1:200.000. *Departement of Geology and Minerals of Vietnam, Hanoi*.

[3] Reineck, H. E., and Singh, I. B., 1973. Depositional sedimentary environments. *Springer*. Pp. 439.

[4] Nguyen Tien Hai, Do Canh Duong, 2010. Characteristics of erosion and accumulation and evolution in the estuarine regions of Lam river in Holocene. *Scientific Conference on 35th Anniversary of Vietnam Academy of Science and Technology, Hanoi*, 10/2010, Pp. 110–116.

[5] Tran Trong Hue, 2005. Study on geological hazards and prevention measures. *Scientific Conference on 30th Anniversary of Vietnam Academy of Science and Technology, Book III*, Pp. 329–344.